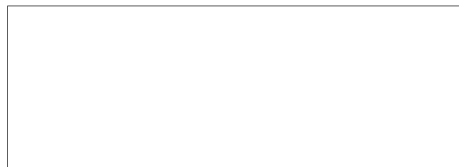


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file - portable hydrogen generator



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April 3, 1957



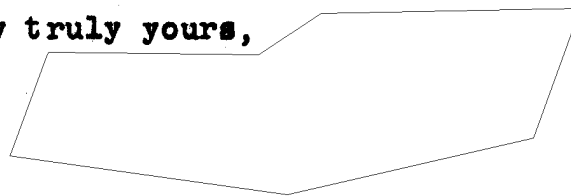
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Dear 


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Sam
Enclosed is a progress report. Annex A is not enclosed, but will follow within a few days.

Very truly yours,



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*Hand carried to
ED by 
4/11/57 - rec'd 12:30*

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PROGRESS REPORT

Generation of Hydrogen for Inflation of Balloons

The purpose of the project is to devise a means for generating hydrogen with minimum weight of materials plus apparatus, water being regarded as free. It is essential that the reaction used be rapid but controllable, and that it require minimum attention on the part of the operator once started.

The following materials come into consideration as primary reactants. The figure of merit attached to each is the ratio of gross balloon lift to weight of the reactant.

Diborane	5.26
Lithium borohydride	3.71
Lithium hydride	3.39
Sodium borohydride	2.13
Lithium aluminum hydride	2.07

The use of diborane may be practical, as it is now available in commercial quantities, but since it is explosive, spontaneously inflammable, and highly toxic, it is not further considered here; however, in view of its very high lift-to-weight ratio and the light weight of the apparatus to use it it should be further considered.

Lithium borohydride would appear to be a promising material but so far as is known it is not commercially available.

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Next in order comes lithium hydride, with which this report is mainly concerned, but at the start of this project this material was thought too difficult and too costly to obtain commercially, and attention turned to the possibilities of lithium aluminum hydride, which is commercially available in large quantities.

Experiments with 10 gram lots of this material in glass apparatus indicated that the direct reaction with water would be very difficult to control. In the same scale and apparatus it was found that reaction of lithium aluminum hydroxide with a solution of water in dioxane was readily controllable, and that the dioxane could be recycled through the process, so that the net result was reaction of water with lithium aluminum hydride, in the presence of dioxane in amount of thirty percent of the weight of the lithium aluminum hydride as a moderating agent. Nothing was observed in these experiments which would cast doubt on the feasibility of using this process on a large scale, though there were several minor explosions and fires; however, the added weight of the dioxane which would have to be supplied decreased the already low lift-to-weight ratio, and the presence of traces of dioxane vapor in the gas might decrease the strength of the balloon material. The question of using lithium hydride was accordingly raised, though with the assumption that the use of dioxane or a similar substance would be necessary in this case also.

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Incidentally, substitution of ethylene diamine for dioxane as moderating agent, which has theoretical advantages, was also tried, but was found unsuitable by reason of side reactions which prevented recycling of the ethylene diamine, by erratic reactions rates, and minor explosions and fires.

First experiments with lithium hydride in 10 gram lots and glass showed that it worked well with dioxane but not with ethylene diamine. Then it was found that dioxane was not necessary and that the reaction was readily controllable when pure water was used. There have been no explosions or fires with lithium hydride, and even deliberate attempts to make it explode by sudden addition of large amounts of water have failed.

First laboratory experiments with lithium hydride and pure water were made by constant additions of water, but it was realized that this would be impractical in the field. A siphon arrangement, made of glass, was put together, which used the force of expansion of the gas to lift water from the source (a laboratory test jar in these experiments) into the reaction vessel. It was found that by this arrangement the reaction was self-supporting and controllable from beginning to end.

At this point the laboratory work was stepped up to the 200 gram scale. It was considered too dangerous to carry out these experiments indoors, not that there was thought to be any danger of fire or explosion of the reactor, but that if the apparatus should fail and the hydrogen get into the

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room a chance spark might set off an explosion. The experiments were accordingly done in a swamp near the laboratory where there is a sluggish stream. An accoutⁿ of these experiments is given in Annex A.

At a demonstration of this apparatus the question of the temperature of the exit gas was raised. A preliminary experiment in the swamp, in which the temperature of the exit gas was taken with a mercury thermometer, whose readings were compared with a matching thermometer in the stream, showed no difference between the temperature of the exit gas and that of the stream water. This may seem astonishing, in view of the large amount of heat developed by the reaction, but it should be remembered that the exit gas passes through large volumes of water in the syphon, and that this water comes directly from the stream. Evidently the heat exchange is nearly complete.

At the time these last experiments were made in the swamp the temperature was near freezing, and the question whether this substantial equality of temperature would persist at higher ambient temperatures was raised. This could only be determined by bringing the apparatus back to the lab, but in view of trouble-free experience in the swamp this was deemed safe. In fact the apparatus cracked and some gas escaped in the first trial in the lab, but fortunately this did not ignite.

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Second and third experiments of this kind in the lab were successful, but as the ambient temperature in the lab was then below freezing it was hard to hold the temperature of the simulated stream (a plastic tub) constant. As a result of fluctuations in both the ambient temperature and that of the "stream" some discrepancies between the readings of the two thermometers were observed, both plus and minus. The measured temperature of the exit gas was never more than 5 degrees above that of the "stream" and there is no reason to believe from these experiments that there is any difference as large as one degree between the temperatures of the exit gas and the stream.

Plans

At this point it was deemed desirable to expand the scale of operations 10 fold, and a 22 liter flask with appropriate tublatures, plus an assortment of glass syphons, was ordered. Corning glass work was the only supplier willing to undertake this large piece of glass-blowing. Delivery of this apparatus is expected within a few days.

Everything which has been observed to date on the reaction of water with lithium hydride suggests that the rate of solution of solid lithium hydroxide, which forms as a crust on the lithium hydride, is the rate-controlling process. It has been experimentally established that the rate of reaction of lithium hydroxide with a saturated solution of lithium hydroxide is very slow. The solution of a piece of lithium hydride originally one half inch on an edge requires days, though reaction, as evidenced by rising bubbles of gas, never stops completely. The experiments to date also suggest that the temperature coefficient of the rate of this reaction is quite small, but this matter is

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so important to the overall success of the project that it requires further investigation. A thermostat for conducting these tests at constant temperature at known concentrations of lithium hydroxide has accordingly been constructed and preliminary tests have been made, but these are not yet conclusive. These tests are being continued.

Also planned are the following:

1. Evaluation of the fire and explosion hazards by detonating blasting caps in two liter flasks of lithium hydride while these are totally immersed in water, and by dumping charges of lithium hydride of the order of pounds directly into water, followed by ignition by a flame. These tests will be made in the swamp.
2. Analysis of the exit gas for poisonous materials, including phosphine and arsine.

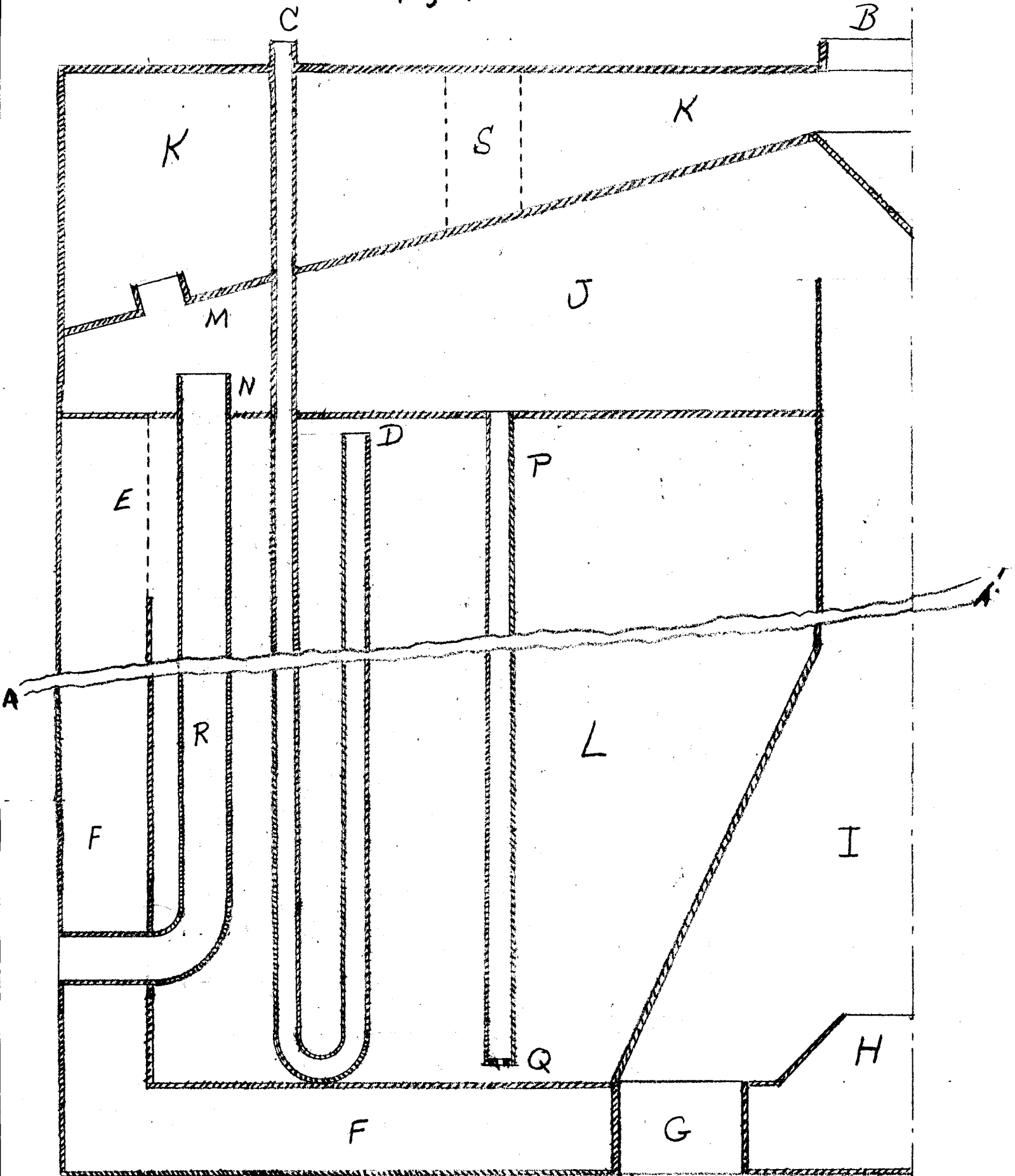
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Figure B1



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Annex B

The Proposed End-item

The proposed end-item is designed to provide hydrogen for 300 lbs gross lift.

Physically it is a cylinder, which may be made of either metal or plastic, approximately 26 inches in diameter and 40 inches high. The empty weight of this cylinder is approximately 60 lbs, and for purposes of transportation it is divided into two parts weighing approximately 40 and 20 lbs. The weight of the necessary accessories, not including the balloon or anything else that actually leaves the ground, is estimated at 20 lbs. The weight of the charge of lithium hydride is approximately 120 lbs. making the estimated gross weight 200 lbs. divided into at least 6 packages, no one of which weighs more than 40 lbs. External protuberances from the cylinder are all on the top, and none of them exceeds 2 inches in height.

Figure B1 shows a section of the cylinder, to its center line at the right of the drawing, and broken along the lines A,A' to save height in the drawing.

In use the device is placed in a depth of water not less than 24 inches and not more than 30. It is supported on three adjustable legs (not shown in the diagram) which stick into the bottom and hold the device firmly in place. At the time this emplacement is made the device is leveled within 2 degrees by means of a spirit level which is part of the kit.

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On top of the device are two openings. The opening and tublature marked B is the outlet for the hydrogen produced. The opening and tublature marked C is for the priming water supply. This comes from a conical rubber bag (not shown) supported above the device by attachable masts (not shown) and holding approximately 8 gallons.

Operation of the device is as follows: It is brought to the scene of operations in two major pieces, as explained above, and the filling and the accesories are brought as separate packages. The device is assembled at the scene of operations on dry land, and is then anchored on its supporting pegs and leveled in approximately 2 feet of water. At this time the bottom of the rubber priming bag is closed off by a stop-cock (not shown). This bag is then filled with water by dipping from the stream with a rubber pail (one of the accesories supplied). When the balloon has been attached the operator opens the stopcock of the rubber bag. This starts the device, which thereafter requires no further attention.

When water flows from the priming bag through C it overflows at D onto the charge of lithium hydride. The hydrogen so formed comes out through the wire mesh E into the annular space F, past the water entrance ports G (there are twelve of these, only one of which is shown in the drawing, with space between them so that they do not obstruct the flow of hydrogen past them to the orifice H) and out the orifice H.

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Since the interior of the balloon is at atmospheric pressure spaces K and J are also at approximately atmospheric pressure and space I is originally filled with water, which gets in through the ports G. Space L, which contains the charge of lithium hydride, and the annular spaces F go above atmospheric pressure when priming water flows in through C and D. As soon as this increased pressure due to generation of hydrogen exceeds the hydrostatic pressure at the level of the bottom of space L hydrogen begins to flow through port H into the water in space I. Rising through I this gas entrains water and delivers it to space J. In space J the water separates from the entraining gas, the water filling space J to the level of the tublature N, and the gas going into space K through the ports M, of which there are a total of 24.

As soon as the bottom of space J is covered with water this fills tubes P, which are of sufficient diameter to fill without entrapped bubbles. There are 24 of these tubes P, only one of which is shown in the drawing. When these tubes are filled the hydrostatic pressure developed in them is sufficient that water flows out through the orifices Q into the space L which contains the lithium hydride. Thus the reaction is kept going by the addition of fresh water which enters through ports G, is pumped up by the gas flowing out of port H and up through space I, through space J into the tubes P, and thence to the lithium hydride.

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As the reaction proceeds space L gradually fills with a solution of lithium hydroxide, and this spills over through the wire screen E into the annular space F whence it is forced out by the pressure of the hydrogen into the space I. Some of it goes round the circuit into the reaction space again, but the greater portion mixes with the outside water by surges through the ports G. Some of it also gets to the outside water through the tublature N as will be described in the following paragraphs. Thus the lithium hydroxide produced by the reaction along with the hydrogen is removed from the system.

The flow of dilute lithium hydroxide solution through the tubes P and the orifices Q (which are equipped with flapper valves, not shown, to prevent back-flow of gas through these orifices during start-up) is less than the amount of dilute lithium hydroxide solution pumped from space I into space J. This excess of dilute lithium hydroxide solution fills space J to the level of the top of the tublature N. Further excess of dilute lithium hydroxide solution flows out of space J through the tube R to the stream. Tube R contains a check valve (not shown) which permits free flow of liquid, but not of gas, which otherwise might be forced out through this tube during a transient oscillation, and so lost to the balloon.

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The gas in space J may be expected to contain water vapor in amount corresponding to the vapor pressure of water 5 or 10 degrees F above that of the stream. It may be advantageous to have the gas going to the balloon substantially dry. If this is worth the extra effort and weight the annular space S, included between two cylinders of wire screen, may be filled with relatively finely divided and uniform sized lithium hydride. Theoretically, this additional lithium hydride should produce as much hydrogen as a dryer as it would in the main reaction chamber, but practically this will not be the case, because lithium hydride used as a drying agent will not be completely consumed, whereas lithium hydride in the main reaction chamber is.

Lithium hydride of the quality and consistency required will cost approximately \$ 10 per pound, or roughly \$ 1,000 per charge. The cost of container plus accessories, in lots of 10 or more, is estimated at \$ 500.

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